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Teachers' epistemological beliefs and efficacy beliefs about mathematics

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Abstract

The purpose of the present study was to examine primary school teachers' epistemological beliefs and teaching efficacy beliefs about mathematics and the relationship between these two constructs. Two paper and pencil questionnaires were administered to 184 in-service and pre-service teachers. Exploratory factor analysis yielded five epistemological factors that were labelled: *simplicity* of knowledge, *certainty* of knowledge, *innate* ability, *source* of knowledge, and *speed* of learning. Participants in general stated quite efficacious to teach mathematics. The regression analysis showed that epistemological beliefs predict teaching efficacy beliefs and vice versa. Implications of these findings concerning the teaching and learning process are discussed.

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Keywords: Epistemological beliefs; teaching efficacy beliefs; mathematics; pre-service teachers; in-service teachers.

1. Introduction

The notion of epistemological beliefs (EB) (beliefs concerning the nature of knowledge and learning) about mathematics has in recent years attracted much attention from several researchers worldwide (Op 't Eynde, De Corte, & Verschaffel, 2006; Schommer, Duell, & Hutter, 2005; Esterly, 2003). There is a widespread agreement within the mathematics community that commonly held EB are detrimental to students' learning, performance and motivation (Muis, 2004). Further, findings from a limited number of studies suggest that there is a positive relationship between *epistemological beliefs* and *efficacy* or *teaching efficacy* beliefs (TEB) (Esterly, 2003; Hofer, 1999). Ashton and Webb (1986) contend that TEF "can be expected to have different relationships to different subject matter, depending on teachers' beliefs about the subject being taught" (p. 139). It is possible, that teachers' EB influence their definition of the teaching task, thereby impacting their teaching efficacy (Esterly, 2003).

Taking into consideration the results of previous studies and the suggestions for further research in the field (see Muis, Bendixen, & Haerle, 2006), we examine the structure and the level of EB, and the level TEB of primary teachers with respect to mathematics and investigate the relationship between these two constructs, a relationship that might be crucial in the process of mathematical learning.

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2. Theoretical Background and research goals

2.1 *Epistemological beliefs*

The construct EB is a subset of the wider belief system, defined to be one's conceptions about the nature of knowledge and learning (Schommer, 1990). Contemporary research on EB stems from the pioneer work by Perry (1968), who examined college students' beliefs about the nature of knowledge and the source of knowledge (Duell & Schommer, 2001). Perry's model comprised nine epistemological positions through which students' EB about knowledge mature/develop. The first three positions involve bipolar thinking (right/wrong), which are next replaced by consideration of multiple positions presupposing acceptance of relativism. The more advanced views lead to the formation of personal positions that may differ from the views of significant others in the social environment.

However, Schommer's work was the one that played a decisive role to later research (1990). She proposed that EB be conceived as a multidimensional construct and suggested that to capture the complexity of EB, personal epistemology should be perceived as a system of more-or less independent beliefs. In this respect, Schommer hypothesized five different sub constructs or dimensions of EB, namely: the structure of knowledge (ranging from isolated bits to integrated concepts), the stability of knowledge (ranging from certain to evolving), the source of knowledge (ranging from handed down by authority to derived from reason and evidence), the speed of learning (from quick or not at all to gradual), and the ability to learn (ranging from fixed at birth to improvable) (Schommer et al., 2005). However, in her efforts to empirically verify these dimensions through factorial analysis of students' responses to her well known 63-item Epistemological Beliefs Questionnaire (EBQ) she found only four out of the five dimensions (Schommer, 1990). Specifically, her analyses did not yield the dimension source of knowledge.

In her attempts to classify beliefs along the above dimensions, Schommer (1990) characterized beliefs in each dimension along the ends of a continuum ranging from "naïve" or "sophisticated", respectively (Muis, 2004). More concretely, Schommer characterized as naïve believing that knowledge is certain, that is comprised of isolated pieces, handed down by authority, that the process of learning is quick, and the ability to learn is fixed and innate. On the contrary, a person who holds the opposite beliefs is considered to have "sophisticated" beliefs. Muis (2004) considered that the terms "sophisticated" and "naïve" carry a value judgment with positive and negative connotation. Instead, she proposed the terms "availing" and "non-availing" respectively (p. 323); we shall adopt these terms in the remaining of this paper.

The importance of teachers' EB derives from a general feeling, which was experimentally verified, that they affect teacher's behaviour and consequently students beliefs and learning (Schommer-Aikins, 2004). While epistemological research initially focused on how students' beliefs mature over time, by the early 1980s and into the 1990s, research began to focus more specifically on how these beliefs mediated students' behaviour and more specifically how students' beliefs mediated cognitive and motivational factors that underlie learning and performance (Muis, 2004). Many researchers found that students with more availing belief profiles had higher levels of motivation and task performance in general (e.g., Buelh & Alexander, 2005) and were also more successful in mathematical problem solving (Schommer et al, 2005).

Another issue that has attracted much attention in the EB research concerns the "domain specificity" versus domain generality. Much of the early work on students' beliefs about the nature of knowledge and learning was conducted with the implicit assumption that the concept of EB is domain general (Muis, 2004). Later on, however, the majority of studies that has been conducted in this line of inquiry suggest that EB may vary depending on the domain under consideration (Buelh & Alexander, 2001). In general, the findings of the above mentioned authors revealed that students' epistemological beliefs about mathematics were less availing than their beliefs about other fields of study, such as history (Muis, 2004). Nevertheless, given the epistemological similarities and differences across domains that can be identified from empirical and philosophical considerations, some of the more recent studies make reference to the dual nature of EB and propose that beliefs are both domain general and domain specific (Muis et al, 2006).

2.2 *Teaching efficacy beliefs and their relation to epistemological beliefs*

According to Bandura (1997), perceived self-efficacy is defined as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 3). Similarly, teaching efficacy beliefs

(TEB), a construct which has long been extensively investigated in educational settings (see e.g. Esterly, 2003; Tschannen-Moran & Woolfolk Hoy, 2001), can be defined as teachers' beliefs in their capabilities to organize and orchestrate effective teaching-learning environments (Philippou & Christou, 2002). Several studies have shown that confidence in one's ability to undertake a certain action is the best predictor of behaviour for accomplishing the task (Bandura, 1997; Pajares, 1996).

Numerous studies have examined whether TEB change over time. Their results suggest that during fieldwork pre-service teachers' efficacy beliefs were amenable to change (Charalambous, Philippou, & Kyriakides, 2008), and increased significantly over the period of time that the pre-service teachers were enrolled in a mathematics methods course (Esterly, 2003). Further, according to Philippou and Christou (2002), teachers' efficacy beliefs tend to get worse during the first period of professional life and improve subsequently, during their career, through experience. That was more or less expected as the initial shock of the complexities involved in the teaching profession is gradually absorbed by most young teachers.

Esterly (2003), also investigated to what extent pre-service teachers' mathematics EB may influence changes in their efficacy to do and teach mathematics. The results revealed that EB did not influence the change in mathematics teaching efficacy, however, the results of the initial analysis (data collected at the beginning of the experiment) provide support for the argument that the higher a pre-service teacher's mathematics EB level of sophistication, the higher his or her mathematics teaching efficacy. These results are in line with the conclusion by Hofer (1999), who found that the level of sophistication of EB was correlated with mathematics self-efficacy. Students with more sophisticated mathematics beliefs reported that they were mastery-oriented and believed they were capable of being successful in the mathematic course.

Despite the interest in the field, the number of studies examining the relation between EB and TEF, like the aforementioned, is extremely limited. Therefore, further exploration is required in order to gain a better understanding of how these two constructs are related, especially in the field of mathematics. Consequently, the purpose of the present study was to examine the relationship among teachers' EB about mathematics and their efficacy beliefs in teaching mathematics. More specifically we sought answers to the following three questions:

- (a) What is the structure of pre and in-service Cypriot teachers' EB in mathematics?
- (b) How efficacious do pre and in-service Cypriot teachers feel to teach mathematics?
- (c) What is the relationship between epistemological and efficacy beliefs of Cypriot teachers with respect to mathematics?

3. Methodology

3.1 Participants

The participants in this study were 184 persons, 147 in service primary teachers and 37 pre-service primary school teachers. The group of pre-service participants were in the final semester of a four-year bachelor degree programme at a state university in Cyprus, with a specialization in mathematics.

3.2 The test Batteries

Two paper-and-pencil questionnaires were administered to all participants; one measuring EB and the other measuring TEB with respect to mathematics. The first questionnaire consisted of 27 Likert-type items, most of which were adopted from Schommer's EBQ. These items were translated and modified to serve the purpose of the present study. Subsets of items were aimed to measure each dimension of epistemological belief including: (a) the structure of knowledge (8 items), (b) the stability of knowledge (4 items), (c) the speed of learning (6 items), (d) the ability to learn (5 items) and (e) the source of knowledge (4 items). The second questionnaire aimed to measure TEB and included also 27 items which were taken from published research mainly from Philippou & Christou (2002). All the items of both questionnaires were on a 5-point Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree). Where appropriate, participants' responses were re-coded so that higher numbers indicated more availing EB and higher level of TEB, respectively.

The data were analyzed using the statistical package SPSS. To answer the research questions of this study, multiple methods of analysis were performed, including factor analysis, regression analysis, analysis of variance

(ANOVA), hierarchical Cluster analysis and t-test. Descriptive Statistics were also used. Cronbach's alphas were found satisfactory for both scales ($\alpha=0.85$, for EB and $\alpha=0.83$ for TEB).

4. Results

To address the first research question, exploratory factor analysis was applied to participants' responses on the first questionnaire measuring EB. Only items with factor loading greater than 0.4 (16 items) were retained in the extracted factors. Table 1 shows that the analysis yielded five factors representing the respective dimensions of EB and explaining 59.6% of the variance.

Table 1. Factor analysis of the epistemological beliefs about mathematics

	1	2	3	4	5	H ²
Information learned in mathematics is useful outside of school.	.758					0.671
Mathematics relates to day life.	.748					0.583
Doing mathematics involves exploration and creativity.	.719					0.607
A math problem can be approached in several different ways	.541					0.410
In math, there are <i>no</i> absolute truths.		.857				0.761
Mathematical formulas that exist now will also be valid in the future.*		.819				0.717
Even if I limit my knowledge to what I know now, I will be able to teach mathematics in the long future. *		.781				0.625
Mathematical genius is 10% innate ability and 90% hard work.			.645			0.546
The really smart students don't have to work hard to do well in mathematics. *			.631			0.489
Only certain people can learn mathematics.*			.617			0.598
If a student is <i>not</i> naturally gifted in mathematics, they can still learn the class material well.			.574			0.499
You have to accept answers from the teacher even if you don't understand them. *				.900		0.826
I don't feel uncomfortable when students challenge the mathematical concepts I teach.				.850		0.729
Learning math does <i>not</i> happen quickly, even for people who are good at it.					.771	0.647
Students need to see the material many times to understand math concepts.					.680	0.518
Exerting effort to try to understand a tough mathematical concept is a waste of time. *					.454	0.306
Percentage of variance explained %	15.3	15.0	11.1	10.3	7.7	
Cumulative percentage of explained variance %	15.3	30.4	41.5	51.8	59.6	

*Items for which participants' responses were re-coded so that higher numbers indicated more availing EB.

According to the items loaded on each factor, the resulting five EB dimensions were labelled as: simplicity of knowledge (four items, $\bar{x}=4.35$), certainty of knowledge (3 items, $\bar{x}=3.14$), innate ability (4 items, $\bar{x}=3.38$), source of knowledge (2 items, $\bar{x}=3.16$), and control and speed of learning (3 items, $\bar{x}=3.25$).

As it appears from the overall EB' mean score ($\bar{x}=3.53$, $S=0.32$), and from the mean scores of each of the five factors (all were found above 3), the participant teachers hold rather availing beliefs about mathematics. In

particular, participant teachers tend not to believe that mathematical knowledge: (a) is not certain and eternal, (b) is rather complicated than simple and (c) it is not necessarily handed down by authority. Further, they do not believe that the ability to learn is fixed from birth and that the process of learning is a fast process. In order to examine possible differences between pre-service ($\bar{x}=3.72$) and in-service teachers' ($\bar{x}=3.48$) EB, an independent t-test was used. The results of this analysis showed that in relation to EB, there was a significant difference between pre-service and in-service teachers ($t=4.80$, $p<0.05$). That is, the group of pre-service teachers with specialization in mathematics didactics tended to hold more availing beliefs than the group of in-service teachers.

The analysis of the responses on the scale reflecting TEB revealed that, participants in general stated quite efficacious to teach mathematics ($\bar{x}=3.44$). To examine for possible differences between the two groups of teachers concerning TEB an independent t-test was used; no significant difference was found among the group of pre-service teachers and the group of in-service teachers with respect to their perceived efficacy beliefs to teach mathematics ($\bar{x}=3.50$, against $\bar{x}=3.42$, $p>0.05$).

In order to examine the nature of the possible relation between the two variables of the study, linear regression analysis was applied. Firstly, to investigate whether TEB can predict EB, regression analysis was conducted with criterion (dependent) variable the EB score and predictor the TEB score. The analysis revealed that TEB is a statistically significant *predictor of teachers' EB* ($R=0.265$, $p<0.05$), and the following equation was obtained:

$$\text{Equation 1: } EB = 0.204 \times (TEB) + 2.825 \quad (R^2=0.07).$$

A second regression analysis was applied with criterion (dependent) variable the TEB score and predictor the EB score which showed that EB is also a statistically significant predictor of teachers' TEB ($R=0.261$, $p<0.05$). The equation that occurred was the following:

$$\text{Equation 2: } TEB = 0.332 \times (EB) + 2.270 \quad (R^2=0.07).$$

As shown in the above equations in either case the proportion of the explained difference is statistically significant, though quite small.

For a more detailed analysis of the relation between EB and TEB, it was decided to separate teachers into groups according to their EB and TEB. Hierarchical cluster analysis was performed to identify EB and TEB profiles. The analysis revealed that teachers could be clustered in two groups according to their EB (availing beliefs: $N=69$, $\bar{x}=3.85$ and less availing beliefs: $N=125$, $\bar{x}=3.32$) and three groups according to TEB (low TEB: $N=61$, $\bar{x}=2.95$ /average TEB: $N=71$, $\bar{x}=3.41$, and high TEB: $N=52$, $\bar{x}=3.91$).

Then, a descriptive analysis utilizing cross tabulation was employed, which shows the distribution of teachers' EB in relation to their TEB. The analysis confirmed prior results indicating the direct relationship among EB and TEB. More specifically, Table 2 shows that 61 of the participant teachers hold low TEB and 115 hold non-availing EB; the majority of the teachers with low TEB (50 out of 61, 82%) were found to have non-availing EB as well, while 32 of the 52 teachers with high TEB hold availing EB. Also, only 11 out of the 69 teachers with availing EB were found to hold low TEB and only 20 out of the 115 teachers with non-availing EB stated efficacious to teach mathematics. Further, it must be noted that teachers with average TEB may have both availing and non-availing EB, though to a greater degree they hold non-availing beliefs. In brief the cross tabulation analysis has confirmed the finding that teachers who feel more efficacious and confident to teach mathematics also hold more availing EB about mathematics, while on the other hand, teachers with low TEB tend to have less availing EB.

In order to investigate whether the teachers' EB vary in accordance to their group of TEB, an analysis of variance was applied with dependent variable the EB score and independent variable the three TEB groups. The analysis indicated statistically significant differences between teachers' EB in relation to their TEB (Pillai's $F_{(2,181)}=5.90$, $p<0.05$). More concretely, the results revealed that there were differences between the group with high TEB and that with low TEB with respect to their EB. Teachers with high TEB have more availing beliefs than teachers with low TEB.

Finally, to examine possible differences between teachers' TEB in relation to their group of EB, an independent t-test was used. This analysis, pointed out that there is a statistically significant difference in TEB between the two groups ($t=3.36$, $p<0.05$). Teachers with availing EB indicated higher TEB mean score ($\bar{x}=3.57$), than teachers with non-availing EB ($\bar{x}=3.37$).

Table 2. Teachers' distribution according to their TEB and EB

	EB	Availing	Non-availing	Total
TEB				
High		32 (46%)	20 (17%)	52
Average		26 (38%)	45 (39%)	71
Low		11(16%)	50 (43%)	61
Total		69 (100%)	115 (100%)	184

5. Discussion-Conclusions

The purpose of the present study was to explore the structure and the level of EB held by Cypriot teachers based on Schommer's framework (1990), the level of their TEB and the relation between these two constructs. The results concerning the structure of teachers' EB indicated that a multidimensional model is applicable and that the structure of EB consists of five factors namely: certainty of knowledge, simplicity of knowledge, speed of learning, ability to learn and source of knowledge. These results are in line with the dimensions hypothesised by Schommer (1990). It must be noted, however, that we found the dimension "source of knowledge" which did not occur in her results. We note, however, that the specific dimension (source of knowledge) that appeared in our study was also found by Philippou, Monogiou and Kaouri (2009), in a study concerning primary teachers in Cyprus, as well as by Chan and Elliott (2004), in their study with pre-service teachers.

This difference with respect to the dimensions of EB might be attributed to the fact that the questionnaire in the present study was modified and the adaptations were deemed necessary due to the specific subject domain (mathematics). Also, the fact that Schommer's findings did not replicate in exactly the same way in this study implies that cross-cultural differences might exist in EB. Further research is needed to deepen our understanding about the appropriateness of the tools we use for measuring subject specific EB in domains such as mathematics and also to search through comparative studies for possible reasons that might explain cross cultural differences.

The results indicated that Cypriot teachers' study hold generally availing EB about mathematics since the overall mean score on the EB questionnaire was above the neutral value 3. Moreover, it seems that the specialization on the didactic of mathematics affect or it is at least related to teachers' EB, since the findings revealed that pre-service teachers hold more availing EB than in-service teachers. On the other hand, no significant differences were found between the two groups of teachers in relation to their TEB, yet what is obvious is that all teachers stated quite efficacious to teach mathematics. This feeling of confidence in teaching mathematics was also evident in earlier study with Cypriot teachers which was conducted by Philippou & Christou (2002), and where the overall mean efficacy as measured by the questionnaires was found to be above the neutral level.

Our findings concerning the relation between EB and TEB are line with other researchers' results (Esterly, 2003; Hofer, 1999). However, the primary aim of the present study was not just to look for the relation among these two constructs, but to search for the nature of this relationship. In this respect, the results revealed that TEB can predict EB and vice versa, EB predict TEB. Even though the equations that occurred explain a small proportion of variance, the relation between the two variables was statistically significant and was found to be supported from the analysis (hierarchical cluster analysis, cross-tabs) that followed. It was found that: (a) teachers with availing beliefs indicated also the highest TEB while teachers with non- availing beliefs had also the lowest TEB and that (b) teachers with high TEB hold more availing beliefs than those with low TEF, which seem to have the less availing beliefs.

The results of the present study seem to confirm and extend prior research outcomes, drawing attention on the epistemological and the efficacy beliefs with respect to mathematics. Future research is needed to investigate in more depth the relationship between the two dimensions, using both quantitative and qualitative data and to examine whether the same results occur with a larger sample. Further, a major issue that remains for future research concerns the design of intervention projects aiming to enhance prospective teachers' EB and TEB, extending and solidifying the work proposed by Esterly (2003) and Charalambous et al. (2008). The findings of this study can contribute to

teachers' effort to help future teachers develop availing EB and also to the design of appropriate activities that will effectively improve teachers' beliefs and increase their confidence in teaching mathematics.

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